Sediment Transport by Internal Waves in EUROSTRATAFORM

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LONG-TERM GOALS

The overall long-term goal of EUROSTRATAFORM is to advance our understanding of the development and modification of sedimentary deposits and sequences on continental terraces (shelves and slopes) in the Mediterranean Sea. Specifically, field studies of modern sedimentary processes will focus on two regions: along the central and northern Adriatic Sea off Italy, and in the Gulf of Lyons off southern France.

This project investigates the role that shoaling internal waves might have in affecting sedimentation in these two regions. The overall long-term project goal is to determine the modes and mechanisms of transport of bottom and suspended sediment by internal waves. The primary emphasis of the research is to examine the available information on internal waves and density structure in the northern Adriatic Sea, and to make preliminary estimates of internal wave effects on sedimentation in both regions.

OBJECTIVES

- Evaluate the role of internal waves in resuspending and transporting sediment on the shallow sections of the Adriatic continental shelf off central Italy (water depths < 100 m) and on the shelf and slope off southern France.

- Install temperature sensors on the shallow mooring deployed in the Adriatic Sea to investigate variability in the internal wave field.

- Collaborate with other investigators to determine the effects of internal waves in transporting sediment in both study areas.

- Develop relationships for estimating internal wave-induced bottom stresses that can be applied to sediment transport calculations.

APPROACH

This project is primarily focused on the interaction of internal waves and the seabed. The approach will extend the internal wave-slope sedimentation model developed in STRATAFORM to EUROSTRATAFORM sites. We will use historical and newly acquired data on internal waves and sedimentation processes in EUROSTRATAFORM to estimate internal wave effects on sedimentation.

We also will develop relationships for predicting sediment entrainment by internal waves, and apply them to modern sedimentation processes in both the Adriatic Sea and Gulf of Lyons. Additionally, we will assist with planning and coordination of field experiments in the both study areas.

This effort is aimed at three specific tasks: (1) continued development of a model for inhibited deposition and possible erosion by internal waves over sloping bottoms; (2) planning and coordination of field measurements of sedimentary processes in the Eurostrataform study areas; and (3) interpretation of density profiles and current measurements related to internal wave and sediment dynamics the field regions.

WORK COMPLETED

- We gathered available data on density structure and bathymetry in the Adriatic Sea. The density profiles in the northern Adriatic off Italy were used to compute Brunt Vaisala frequencies.

- We calculated characteristic angles (i.e., group velocity vector directions) from the BV frequencies and internal wave frequencies that have been reported for the region (both high frequency and near-inertial frequency internal waves).

- We made estimates of bottom velocities and bottom shear velocities from simple linearized analytical models of shoaling internal waves using available bathymetry and density data.

- We organized a special session on Internal Waves and Seabed Effects for the Annual Fall Meeting of the American Geophysical Meeting (December 6-10, 2002 in San Francisco). This special poster session was highly successful, and drew contributions from many researchers involved in this topic.

- Time-series temperature (T) data were obtained over a four month period from recording T sensors mounted on a shallow mooring in the Adriatic study region (PASTA experiment).

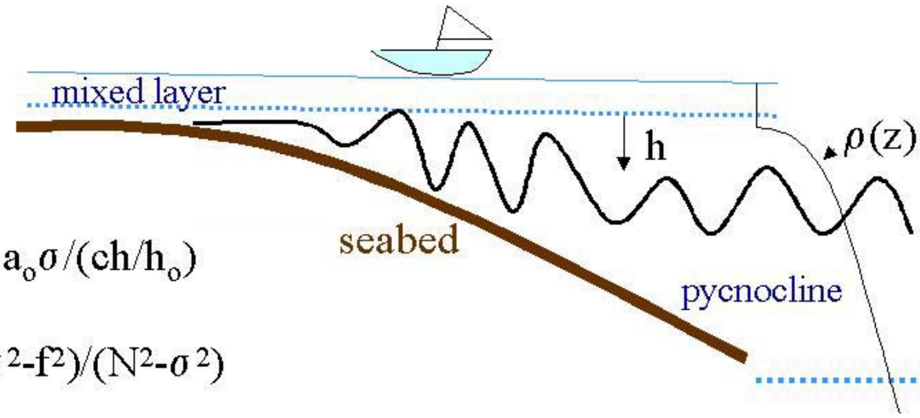
- Initial analysis of the temperature data has been completed.

RESULTS

The effects of internal waves and tides on transport of bottom and suspended sediment are poorly understood. We have approached this problem both theoretically and using new data collected during the first EUROSTRATAFORM field experiment. The findings to date indicate the following results.

- Measurements of the upper (seasonal) pycnocline in the PASTA study region indicate considerable variability in the seasonal pycnocline. The strength of the density gradients vary from nearly well-mixed (after large storms) to prolonged periods of high stability. During the periods of high stability, Brunt-Vaisala frequencies can be rather high (up to 15 cph). Figure 1 illustrates the strong stratification that can occur in the PASTA study area, along with a schematic of high-frequency IWs over the shallow shelf region. The expression for bottom velocity comes from earlier work by the author (Cacchione and Southard, 1974). Note that "c" is the formulation for the direction of the group velocity vector for internal waves, and is dependent on wave frequency, Brunt-Vaisala frequency (N), and local inertial frequency (f). N is prescribed by the density gradient.

Bottom velocity (u) for shoaling high-frequency IW's



$$u_{max} \sim a_o \sigma / (ch/h_o)$$

$$c^2 = (\sigma^2 - f^2)/(N^2 - \sigma^2)$$

σ = internal wave frequency
f = inertial frequency
N = stability frequency
a_o = IW input amplitude
h = adjusted water depth

- Internal waves of high frequency (2-6 cph) and at near-inertial frequencies were found during PASTA. Near-inertial internal waves have been shown to cause sediment resuspension and to generate bottom nepheloid layers in other regions of the western Mediterranean (e.g., off southern Spain), and we anticipate similar processes here.

- Theoretical estimates of bottom velocities caused by shoaling high-frequency internal waves exceed threshold values for entrainment of natural bottom sediment on some shelves. Initial estimates for the PASTA study area using a linear model suggest that bottom velocities exceeding threshold sediment entrainment velocities (~ 20 to 30 cm/s) might be achieved. Figure 2 presents some initial calculations of bottom velocities for high frequency internal waves in the PASTA region. "γ" is the approximate gradient of the bottom in the study area. Data from an instrumented mooring and bottom tripods during PASTA will be used to investigate this process more fully.

High-Frequency IW's on a slope

($\gamma \sim 0.006$ in PASTA region)

u_b = max. bottom velocity

$u_b \sim a_o\, \sigma/(ch/h_o)$

Table 1. Calculations of c and u_b

	N = 6 cph		N = 16 cph	
σ, cph	**c**	**u_b, cm/s**	**c**	**u_b, cm/s**
0.33	**0.055**	**2.1**	**0.021**	**5.5**
1.0	**0.169**	**2.1**	**0.063**	**5.5**
2.0	**0.125**	**5.6**	**0.016**	**43.5**

$h/h_o = 0.5$; $a_o = 1$ m

- Near-inertial internal waves have been shown to generate near-bottom nepheloid layers by resuspending fine sediment from slopes in the western Mediterranean off Spain (Puig, et al, 2002). We intend to investigate this process in the PASTA region using new time-series measurements of currents and density that were collected during 2003.

IMPACT/APPLICATIONS

Internal wave-induced bottom stresses might have a major influence on controlling erosion and deposition on shelves and slopes in the oceans and in the Mediterranean Sea. If the high-frequency and near-inertial internal waves are as energetic in the study areas as have been reported in other regions, they would be important processes for transporting fine sediment. They might also contribute to the formation and modification of bedforms that have been observed along the Adriatic shelf and on the outer shelf in the Gulf of Lyons.

Also, if high frequency internal waves shoal and break along the seafloor in the seasonal pycnocline, erosion and resuspension of bottom sediment might occur. This process could lead to dispersal of sediment, and generation of turbid bottom layers.

TRANSITIONS

This work has applications for modeling of formation of sedimentary strata and structures on continental shelves. It may also have implications for sedimentation on certain continental shelves where turbulent shears from surface waves and other currents are relatively low (as compared with internal wave effects). The results and model can be integrated into more comprehensive sedimentation models that are under development by others (e.g., J. Syvitski and L. Pratson).

RELATED PROJECTS

The internal wave work is being done in close collaboration with other EUROSTRATAFORM investigators: Dr. Andrea Ogston (U. of Washington), Dr Pere Puig and Dr. Alberto Palanques (both at Ciencies del Mar, Barcelona, Spain), Dr. Serge Berne (IFREMER, Brest, France), and Dr. Lincoln Pratson (Duke University).

This project is closely related to those EUROSTRATAFORM projects investigating morphology and surface sedimentation on continental shelves. The work is related to projects led L. Pratson (Duke University), C. Nittrouer, and A. Ogston (all three at University of Washington), J. Syvitski (INSTAR, University of Colorado), and M. Steckler (Lamont-Doherty Geological Observatory).

REFERENCES

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Puig, P., Palanques, A., Guillen, J., and D. Cacchione. 2002. The role of near-inertial internal waves in the sediment dynamics of Mediterranean continental shelves, EOS, Trans. Amer. Geophysical Union, Fall Annual Meeting, Abstract Number OS11C-0244.